The Weather of Southwest California: A Climate Overview

Climate Zones

Most people visualize the mild coastal climate when asked about the climate of Southern California, forgetting for a moment that there are coastal, inland, mountain and desert climate zones that are highly distinct and very close together. These climate zones are determined by the effects of proximity to the ocean, terrain, elevation and latitude. Using the Koppen system, the more populated areas of Southern California have a Mediterranean climate, characterized by mild, sometimes wet winters and warm, very dry summers. The climate types in the mountains range from Mediterranean, to Subtropical Steppe (not as mild as Mediterranean with more precipitation in all seasons) to Highland (more extreme and variable due to elevation). Desert climate types include Midlatitude Desert, a dry climate with hot summers and cool winters, and Subtropical Desert, relatively hotter and drier. The Mediterranean climate includes all coastal areas, valleys and foothills. Subtropical Steppe climates would include the mountains between the foothills and the higher peaks. Highland climates would encompass the mountain tops, probably above 7,000 or 8,000 feet.

Annual precipitation amounts increase gradually from the coast to the mountain crests, then drop dramatically into the deserts. A graphic of average annual rainfall can be found on the following web site: **www.wrh.noaa.gov/sandiego/climate/pcpn-avg.htm**. California owes its agreeable climate to a semipermanent high pressure area located over the eastern Pacific Ocean, which deflects storms northward and secures fair weather for the region. During the winter months, this high breaks down allowing the jet stream to steer midlatitude weather systems along a more southern track of the prevailing westerly winds. For this reason, most precipitation comes from winter storms between November and March.

Winter Storms

Winter storms bring a great variety of weather phenomena: strong winds, flooding rains, heavy snows, large surf, and thunderstorms with their damaging lightning, hail, winds and the occasional tornado. In Southern California, cold fronts arrive with little resemblance to those described by weather textbooks. The cold air associated with deep troughs of low pressure becomes modified by the mild ocean waters and the front becomes less distinct. Winter storms usually have a leading band of rain ahead of the colder air of the system. With the warmer storms, the majority of the rainfall occurs in these initial bands. Cold storms bring a pool of cold unstable air aloft that follows behind the initial rain band, bringing showers and/or thunderstorms. In these colder storms the majority of precipitation often falls from the showers and thunderstorms rather than the initial band of rain. At times there is a high variability of rainfall distribution. For example, a big winter storm may bring three inches of rainfall to Anaheim, but less than an inch to San Diego. In showery situations, one thunderstorm can drop over an inch of rainfall over one spot, leaving the rest of the area dry. The direction of flow of the lower level winds can indicate favorable areas for more rain than others. If the flow is south or southwest, we expect relatively greater rainfall in Orange County, the northern Inland Empire and especially the San

Gabriel and San Bernardino Mountains. West or northwest flow will bring greater rainfall to San Diego County.

On rare occasions, the subtropical jet stream can direct warm, wet air into California originating from the central Pacific. This stream of moist air is sometimes called the Pineapple Connection or Pineapple Express, because the track often comes from the direction of Hawaii. The air has a greater amount of moisture than the air contained in colder storms, so they tend to bring heavy rain, but little if any snow. When the long wave pattern, or general global circulation, steers this moisture into our region, a wet pattern develops and there can be many days of rainfall. Once the soil becomes saturated, most of the rainfall immediately becomes runoff, which causes flooding and flash flooding. If the rainfall is intense enough, such as in heavy prolonged thunderstorms, the soil need not be saturated, as the water will run off regardless and produce flash floods. Strong winds accompany especially strong winter storms and can cause damage particularly along the coast and in the mountains.

The phenomenon of **El Niño** makes its presence known during winter by altering the traditional path of the jet streams and directing frequent storms into California. With the presence of a strong El Niño, the subtropical jet stream becomes oriented over California, carrying large amounts of warm moist air into the region. Occasionally, the polar jet stream brings a cold front that coincides with the subtropical jet stream and produces massive amounts of rain. Any strong individual storm during the wet season can bring disaster, but the real problem with El Niño comes from the *frequent arrival* of strong storms. They simply continue to exacerbate the problems left by the previous storm(s) and do not allow enough time for people or the environment to recover.

A storm originating from the Gulf of Alaska or Canada obviously will have much more cold air associated with it than a storm from farther south. Cold air aloft contributes to instability, a strong decrease between surface temperatures and temperatures aloft. If instability is great, thunderstorms develop. On occasion these thunderstorms are severe, meaning there is some combination of intense flooding rain, large damaging hail, and/or strong damaging wind.

Thunderstorms pose a number of problems. They bring intense rain, which can cause flash flooding. They contain lightning, hail and very strong wind gusts, which can kill or injure people and damage property and crops. Thunderstorms also develop in warm air masses when tropical moisture is introduced from the southwest monsoon or a decaying tropical cyclone. A thunderstorm is considered severe when winds are strong enough and hail is big enough to produce damage.

Winter storms also bring snow mainly to the mountains. One strong storm can bring a few feet of new snow to the higher mountains. While most Southern California residents do not have to worry about snow at home, we do often have to drive through winter conditions to leave the region. On very rare occasions, an especially cold storm can drop the snow levels to some of the densely populated lower elevations.

When the atmosphere is moist and unstable, convergence of the air at lower levels can produce lines of rising motion called convection. This convection is a circulation of air in the vertical plane and can produce showers and thunderstorms. Topographical barriers such as islands or mountains can induce these convective lines in the proper conditions. Low level winds flow around islands or mountains and converge on the lee side like water in a stream flows around rocks and converges on the other side. As the air converges, the air is forced upward because it cannot sink into the ocean or the ground. The result is a line of convection containing showers and/or thunderstorms parallel to the mean flow extending downwind. We call this lee side convergence. A similar thing happens as a result of the mountains. Zones of convergence can occur on the lee side of mountain ranges between two valleys or mountain passes. For example, air flowing around the Palos Verdes peninsula can produce a line of convection from Long Beach into northern Orange County. This area is also Southern California's "tornado alley." Winds flowing around the Santa Ana Mountains form the "Elsinore Convergence" from Lake Elsinore to Hemet. Smaller similar convergence zones can develop on the north and east sides of all the mountains from Victorville to Mexico.

Winter storms also bring large ocean swell, which translates into large surf. In addition to the obvious dangers for beach visitors and water sports enthusiasts, tidal overflow and erosion of sand and coastal bluffs present many more dangers to life and property.

The Summer Monsoon

The Southwest Monsoon season occurs from mid June through mid September over the southwestern U.S., generally more prominent from Arizona eastward. Occasionally, episodes of monsoonal flow reach Southern California during late summer and bring thunderstorms (sometimes called "Sonoran" storms) mainly to the mountains and deserts.

The monsoonal flow develops as a strong upper ridge builds over the four corners region, which draws warm moist air from Mexico into the Southwest. Perturbations or disturbances in this flow such as an easterly wave trigger convection and thunderstorms. An easterly wave is an inverted low pressure trough within the monsoonal flow that moves from Arizona or Sonora westward into California. At times moist air flows northward from the Gulf of California (Sea of Cortez) further destabilizing the atmosphere. This is called a **gulf surge**. At times, even when the monsoon is absent, the moist air layer of the gulf surge is rather shallow and does not produce thunderstorms; it becomes a sort of hot, humid, desert marine layer. For thunderstorms to develop, the moist air moving into the region needs to be rather deep in the atmospheric column. The heating of the earth's surface further destabilizes the atmosphere and convection results; columns of locally heated bubbles of air rise in the moist atmosphere and grow into towering cumulonimbus clouds and thunderstorms. Sometimes the monsoonal flow spreads a shield of opaque cloudiness over the region. When this happens, convection may be inhibited because the sun is not able to effectively heat the earth's surface and sufficiently destabilize the atmosphere.

In the mountains and deserts, the air from the surface to the cloud level is usually very dry. As the thunderstorm produces rain, the drops fall into this drier layer and may completely evaporate (if falling rain does not reach the ground, it is called **virga**). This evaporation cools the column of air. Because cool air is more dense than warm air, the cool air in the warm environment will sink and accelerate as it descends. This **downburst** of air can reach the ground with damaging force. A highly localized downburst is called a **microburst**. Upon impact with the ground, the winds rapidly spread across the earth's surface as a **gust front**. Some gust fronts, or outflow boundaries, can converge with neighboring thunderstorm outflows. These colliding gust fronts can create new lines of convection.

Flash flooding in rough terrain can be very deceptive. A mountain thunderstorm can flood desert areas with water, mud and rock, even if no rain falls in the desert. Flash floods in areas of steep terrain, impenetrable rocky soil, and little vegetation are the most volatile.

Normally, monsoon thunderstorms are relatively rare west of the mountains, but can occur under the right conditions. If the winds from the mountain top level upward are rather strong from the east or southeast, thunderstorms can drift from the mountains to the valleys and even, in rare cases, to the coast.

The Marine Layer

The marine layer is perhaps coastal Southern California's most dominating weather feature. Proximity to relatively cool ocean waters protects the region from extreme heat or cold. Air at the surface cools by conduction as it comes in contact with the water. When the air above the water is warmer than the water, as it is normally for all seasons except winter, a temperature **inversion** develops. In a normal atmosphere, air temperature decreases with height. An inversion means temperature increases with height through a layer; it is the *inverse* of the standard atmosphere. Cool and moist air is at the surface (in contact with the water) and warmer, drier air is above it. The air is cooled enough to condense and form a stratus cloud layer.

Basic weather knowledge includes understanding of land-sea interactions. During the day the sun warms the land more efficiently than the ocean due to differing surface heat absorbing characteristics. The warmed air over land rises and the sea air moves in to replace it, creating a **sea breeze**. Obviously, the prevailing wind flow with a present marine layer is from the ocean to the land, or "onshore flow." Onshore flow is determined and measured by pressure differences (gradients) between higher pressure over the ocean and lower pressure over the desert. If the gradient is steep, the onshore flow is strong, and vice versa. We often refer to the pressure gradient between Lindbergh Field (SAN) and the Imperial Airport in El Centro (IPL) as a local benchmark.

The depth of the marine layer varies with upper level high pressure and low pressure. High pressure tends to suppress, or squish the marine layer down near the surface and is called a shallow marine layer. Low pressure allows the marine layer to deepen. However, if the low pressure has enough cold air aloft, it can wipe out the inversion. This "busts up" the marine layer, the warm and cold air layers mix, and the low clouds will clear. When the inversion is very strong and relatively shallow, the coastal clouds can stick to the beaches all day.

The common cloudiness near the coast occurs mainly during the night and early morning, then evaporates during the day. The clouds normally clear during the morning as a progression from inland areas to the coast. As the sun begins to warm the land surface (even through the cloud layer), the cloud layer begins to evaporate from the ground upward until the clouds completely evaporate. At dusk, the sun has set and the evaporation slows, so the onshore flow can move the clouds over land without evaporating. Very little mixing takes place between the cool moist marine layer and the warm dry layer above it due to stability. Cold air is more dense than warm air and finds stability or equilibrium at lower levels. As an analogy, the cool marine air is like water in a bathtub, content to stay at the bottom and not mix with the air above it. The clouds will not rise over the mountains without evaporating. If you hike in the sunny local mountains early on a summer morning you can see an "undercast" sky condition, a solid cloud layer below.

A **coastal eddy** is a counter clockwise circulation of low level winds in the California Bight (the California Bight is comprised of the ocean waters fronted by the concave Southern California coastline). Because these coastal eddy circulations are often centered around Santa Catalina Island, it is often called a **Catalina Eddy**. It forms when the air flow aloft becomes cyclonic (counter-clockwise) and when strong northwest winds blow off Point Conception. Those winds continue blowing toward the southeast and naturally curve into the bight. Imagine a pinwheel in the vicinity of Catalina. The stronger winds over the outer waters would spin that pinwheel counter clockwise because the winds in the inner waters are weaker. Eddy formation is accompanied by a southerly shift in coastal winds, a rapid increase in the depth of the marine layer, a thickening of the stratus cloud layer, and often some drizzle. The marine layer can deepen to 6,000' and extend well inland along the slopes of Southern California's larger mountains and even through the lower passes into the deserts near Hesperia and Palm Springs. These occasions are almost always accompanied by drizzle or even light rain. Because the cloud layer is thick and the circulation produces more clouds, it takes much longer to evaporate the cloud layer. Over land the cloudiness can persist into the afternoon or even all day near the coast. Coastal eddies occur predominantly during the "stratus season" - spring and summer. Hence, you hear about "May Gray" and "June Gloom".

At times with a deep marine layer, probably at least 2000' deep, the atmosphere below the inversion can become unstable as the sun warms the land surface. The initial stratus clouds clear, but the warm and moist surface air rises to produce shallow convection and cloud development capped by the inversion. Meanwhile, at the beaches the sea breeze is drawing cool surface air onshore, which stabilizes the atmosphere. In these situations, the coast clears while clouds continuously redevelop inland. This is what we call "reverse clearing" because clearing occurs from the beaches toward inland areas, the reverse of the standard clearing pattern.

Dense Fog can form when the stratus cloud layer comes in contact with the ground, usually along the inland edge of the cloud deck. When the marine layer is deep, dense fog will develop in the mountains and foothills. Fog can also develop as air ascends a mountain slope and condenses. When the marine layer is shallow, the clouds will not penetrate very far inland, staying near the coast. In these cases lower elevations may get dense fog. This kind of fog is called **advection fog** because the fog advects, or moves horizontally from one location to another.

Radiation fog, also called ground fog, is not usually related to the marine layer. It can develop on clear, cold, and calm nights when the air near the surface is moist, such as after a rainstorm. The moist air has a high dew point temperature. As the ambient temperature falls in the evening, it will approach the dew point and fog can develop. This is more common in inland valleys because they are sheltered from the modifying effect of the mild ocean.

Santa Ana Winds and Hot Weather

Santa Ana winds are strong, dry offshore winds that blow from the east or northeast. These winds are strongest below passes and canyons of the coastal ranges of Southern California. The name is derived from the Santa Ana Canyon, which is susceptible to these winds.

The complex topography of Southern California combined with various atmospheric conditions create numerous scenarios that may cause widespread or isolated Santa Ana events. Santa Ana winds develop when a region of high pressure builds over the Great Basin (the plateau east of the Sierra Nevada and west of the Rocky Mountains including Nevada and western Utah). This pressure pattern often follows the passage of an upper low through the interior west. If the upper low moves into northern Mexico or Arizona, the upper level winds will be from northeast, and enhance the northeast surface flow. The cold air associated with the upper low forms a dry front coming from the northeast. Strong subsidence associated with the cold air following these fronts forces strong winds aloft downward to the surface. This creates a turbulent mountain wave that touches the surface on the lee side of the mountains. On rare occasions, there may be precipitation with the system and a “wet Santa Ana” results, but most of the time a Santa Ana event brings clear skies and warm weather. Clockwise circulation around this high pressure area and subsidence (sinking motion) forces air down the mountain slopes from the higher plateau. The air warms and dries out, due to heating by compression, and accelerates as it descends toward the coast. Sometimes the winds are very localized, narrow corridors or rivers of wind, and nearby areas escape them.

Santa Ana winds occur mainly during Fall and Winter and are most common during December. Summer events are rare. A reasonably strong event can produce sustained wind speeds of 30 to 40 mph with gusts over 60 mph. During exceptional events the top gusts can exceed 100 mph. The strongest winds usually occur during the night and morning due to the absence of a competing sea breeze.

The impacts of these winds are numerous. There is always a high fire danger during these events. Trees and power lines are toppled, leading to property damage and power outages. High profile vehicles are at risk of being blown over. Turbulence and low level wind shear adversely affect aircraft, while strong winds can present great danger to boaters.

Fall events can bring hot weather as well as strong winds. Most high temperature records in coastal California have occurred during a hot Santa Ana. Legend and lore have sprung from these uncomfortable conditions. Early Mexican residents called them “los vientos del diablo” - the devil winds. It is a strange time for residents near the coast because their mild climate turns into the Sahara for a time. Fires increase, crime seems to go up, and numerous health conditions worsen, such as allergies. Some claim earthquakes are more likely during this “earthquake weather.” Like the time during a full moon, it just seems that more weird things happen.

Hot weather is relative in our region of wide variations. In the lower deserts it is a staple of life. Near the coast it is a rather rare occurrence. **Extreme heat** most often comes when strong high pressure aloft is present over the region. This produces an atmosphere that is generally subsiding, or sinking. As the air subsides, it compresses and warms as the pressure increases near the surface. When the monsoon flow over the desert southwest sends moisture into our region, this added humidity compounds the danger of the heat. Years ago, the National Weather Service developed the Heat Index to properly account for the body’s reaction to heat and humidity. See appendix F for the Heat Index Table.

Dust devils are products of a heated land surface and do not need extreme heat to develop. On sunny days, the ground heats up in a non-uniform way producing rising pockets of air called thermals. In strong thermals, the rising air develops a spin and the result is a dust devil, a narrow rotating column of air that can sometimes reach several hundred feet into the sky. Dust devils are usually not dangerous, but some can cause minor property damage. They are not associated with tornadoes, since tornadoes develop from strong thunderstorms. They are most common in the inland valleys and deserts of our region.

Tropical Connections: Hurricanes and Their Remnants

Hurricanes need warm ocean waters to survive and grow; as a general rule, the sea surface temperature should be above 80 degrees. Below that temperature, the hurricane will lose its energy and die. The California Current is a cool ocean current that parallels the California coast, maintaining the sea surface temperatures safely below 80 degrees. This is why hurricanes never strike the California coast, but the remnants of tropical cyclones can make a big impact in our region. If the conditions are right, these distant hurricanes can also send large ocean swell to Southern California beaches.

The eastern Pacific hurricane season runs generally from June through October. Hurricanes or tropical storms moving into the cooler waters will decay, but on occasion are strong enough to come very close to California at tropical storm strength and produce a wild, off-season rainfall event with widespread flash flood damage. Some of Southern California’s heaviest rainfall events have been the result.

More likely, only the remnants of these storms will provide a source of warm, moist and unstable air off the coast of Mexico. If the upper level flow is from the south, this unstable air is brought into the region. There is very little rising motion associated with these moist air masses, but the high amount of moisture is sufficient to produce showers. Some local effects can enhance the precipitation. The ocean waters are warmest during late summer, so the stabilizing effect of the normally cool ocean waters is reduced. As these unstable tropical remnants move into Southern California, the orographic (mountain) effect and surface heating provide additional uplift necessary to produce the showers and thunderstorms.

El Niño and La Niña

The term El Niño (Spanish for the "Christ child") was originally used by fishermen along the coasts of Ecuador and Peru to refer to a warm ocean current that typically appears around the Christmas season. The term El Niño has come to be used for these exceptionally strong warm intervals that not only disrupt the fishing industry but also bring heavy rains to the normally dry region. La Niña (El Niño's sister) is the opposite of El Niño, where equatorial Pacific ocean waters are cooler than normal.

Normally in the tropical Pacific Ocean, the trade winds are persistent winds that blow westward from a region of higher pressure over the eastern Pacific toward a region of lower pressure centered over Indonesia. During El Niño years, this atmospheric pressure pattern breaks down. Air pressure rises over the western Pacific and lowers over the eastern Pacific. This change weakens or even reverses the trade winds. This fluctuation in pressure across the Pacific Ocean is called the Southern Oscillation. The normally strong coastal upwelling of ocean waters along the west coast of South America is decreased or stopped by the weakened trade winds and this allows warmer surface waters from the western Pacific to surge eastward toward South America. Because these pressure reversals and ocean warming are concurrent, it is referred to as the El Niño - Southern Oscillation, or ENSO.

The oceans and the atmosphere greatly influence each other. During normal years, the eastern Pacific waters cool the air above. Cool dense air does not easily form clouds and rain, especially in a warm tropical environment, so the coasts of Peru and northern Chile receive very little rain. When the ocean warms, the moist warm air above it becomes buoyant enough to produce rain. This shift in major rain zones has a ripple effect on wind patterns and climatic conditions all over the globe.

The impacts of El Niño and La Niña show up most clearly during the northern winter. El Niño winters are milder over Canada and the northern United States, while cooler and wetter than normal winters are experienced in the southern U.S. During La Niña years, winters are warmer in the upper Midwest and cooler in the Southeast and Southwest. It is wetter than normal in the Northwest and drier than normal in the southern third of the U.S. For more information about El Niño and La Niña, click on: **www.cpc.noaa.gov/products/analysis_monitoring/lanina** or **meteora.ucsd.edu/~pierce/elnino/elnino.html**.

Global Warming, the Greenhouse Effect, and Climate Change

In recent decades it has been observed that the average temperature of the earth is rising. The numerous effects of this rise in temperature can greatly impact global climates and human life. This has produced cause for concern well beyond the scientific community. At the NWS in San Diego, no direct research or study of global warming is performed. For more information on the subject, click on: **ww2.wrh.noaa.gov/climate_info/Global_Warming.htm** and **www.epa.gov/globalwarming**.

Sun, Earth, Sea, Space, and Optical Phenomena

The sun, earth, sea and sky produce naturally occurring phenomena that generate questions directed to the NWS for explanation. These may include solar and lunar phenomena, optics, astronomy, space weather such as aurora borealis or solar flares, ocean behaviors beyond sea state, seismology, volcanology, and geology.

These phenomena do not fall under the expertise of meteorologists at the NWS. Meteorologists may have some knowledge about these phenomena and may offer it, but the knowledge or opinion is not qualified professionally, only possibly from a personal interest or hobby.